

THE ASGARD AND VALHALLA REGIONS; GALILEO'S NEW VIEWS OF CALLISTO K.C. Bender¹, K.S. Homan¹, R. Greeley¹, C. R. Chapman², J. Moore³, C. Pilcher⁴, W.J. Merline², J.W. Head⁵, M. Belton⁶, T.V. Johnson⁷ and the SSI Team, ¹Arizona State University, ²SW Research Inst., ³NASA-Ames Research Center, ⁴NASA Headquarters, ⁵Brown University, ⁶NOAO, ⁷JPL.

On November 4, 1996, the Galileo spacecraft passed by Callisto at a distance of 1219 km. During this flyby regional and high resolution images of two multi-ring structures were acquired: 1640 km diameter Asgard and 4000 km diameter Valhalla. Both structures are characterized by bright central plains encircled by arcuate, discontinuous structural features (ridges, scarps and troughs) and surrounded by ancient, heavily cratered plains (Bender et al., 1994[1]). These structures are thought to have been formed by major impact events early in Callisto's history (McKinnon & Melosh, 1980 [2]; Melosh, 1982 [3]; Schenk, 1995 [4]). Imaging at Asgard consisted of four frames [clear filter] at 1.1 km/pixel, providing a mosaic that covers the entire ring structure. In addition, four color images were acquired in different filters [violet (0.415 microns), continuum (0.757 microns), strong methane (0.888 microns) and 1 micron (0.989 microns)] at 10 km/pixel covering Asgard and latitudes north and south of the ring structure. The improvement in resolution over Voyager reveals that the bright central plains of Asgard may owe part of their high albedo to a young dome crater and its ejecta located in the southwest part of the feature. The large size of the central dome of this crater may be due to the occurrence of the impact within the central region of Asgard and may provide information about the relative strength and mobility of the material forming the interior plains of the large ring structure. By comparing the high-sun Galileo images of Asgard with the terminator Voyager images, greater detail is now revealed, especially in the trough structures. It appears that the interior of some of the outermost troughs have inward facing, possibly rotated, fault blocks. In addition, the transition from scarp zone to trough zone appears less distinct with a more gradual change from inward stepping block faults (scarps) to the trough features. Crater Njord, located SE of Asgard, is seen to be a dome crater, with a somewhat degraded rim and surrounding bright albedo pattern (likely the continuous ejecta blanket). Its overall morphology and albedo are akin to those of an early stage/developing "penepalimpsest" (Passey & Shoemaker, 1982 [5]) and may support the prediction of Iaquinta-Ridolfi & Schenk (1995 [6]) that the penepalimpsests of Ganymede (and Callisto) are relaxed impact craters and their ejecta, with the crater rim located interior to the margin of the high albedo patch.

Imaging of the Valhalla region consisted of four separate high resolution observations. Three are located in various structural regions of Valhalla: one in the inner plains, one in the trough zone and one in the

scarp zone. The Valhalla structural zones differ from Asgard in that there is a ridge zone immediately adjacent to the bright inner plains, and that the trough zone is surrounded by the scarp zone (the reverse is true at Asgard). Places within the scarp zone were observed by Voyager to have a bright, low crater frequency material located at the base of some scarps. This material was suggested to have been emplaced fluidly (Remsberg, 1981 [7]); hence the high resolution scarp observation was designed to image this material. The final observation is of a crater chain found within the Valhalla structure.

The 29 m/pixel image of the inner plain of Valhalla reveals a surface with far fewer craters than anticipated. The surface imaged by Voyager is thought to be relatively old, given the high frequency of craters of all sizes. It was anticipated that all images of Callisto, no matter what the resolution, would continue to show a highly cratered body with craters of all sizes down to the limit of resolution. At moderate to high resolutions it was thought surface would consist of "shoulder to shoulder" craters and crater rims in various states of degradation. While some craters are seen, their characteristic appearance as a landform is being modified such that the craters are apparently disappearing. The predominant surface texture is much smoother and freer of small craters than anticipated and mass wasting is evident in the movement of material down the slopes of small ridges [including, and perhaps consisting entirely of, rims of old large craters]. Crater rims are apparently being reduced to small blocky segments with the rock/dust component of the ice moving downslope to form the smooth, mantling material.

Examination is underway of endogenic (volcanic, thermal, etc.) and exogenic (impact gardening, sublimation degradation [8], etc.) processes which may lead to the surface texture seen in the high resolution images. The relative absence of small craters could be due to a relative lack of small impactors and/or due to a crater erosional/ degradational process(es). There is evidence, from the range of morphologies of the small craters, that it is a fairly continual process that degrades and then obliterates the small craters. This unknown process may also be linked to the production of the dark, smooth material that seems to be accumulating on the surface. However, due to the less-than-equilibrium density of the very small craters, it is clearly not the impact crater/regolith process itself that is obliterating or covering them, although impacts may augment other processes[9]. All features (crater rims, ridges, etc.) appear to be subject to degradation. This

could be a microscale disaggregation process involving the separation of a volatile component that otherwise binds the dark, non-volatile material together. Such a process could, over time, release the material mass wasting down slopes and produce, in situ, the apparent blanketing material seen elsewhere [in areas where no slopes exist to support mass wasting]. In addition, there may be an electrostatic process which could raise the material off the surface and then redeposit it [10], producing the very uniform appearance of blanketing material - in effect "fluffing" the dust/rock. As all the high resolution images to date are of locations within the Valhalla ring structure, it may be that the process producing the observed surface is peculiar to ring structure and may not be present elsewhere on Callisto.

The images of the trough zone show a similar surface texture and lack of small craters. At the margin of the main trough in the observation, small, sinuous ridges are seen which increase in number and decrease in spacing as the margin of the trough is approached. Images at the scarp zone, with oblique geometry and low angle of illumination, reveal that the smooth textured surface is locally hummocky. Measurements of scarp heights using shadow lengths range from 200 to 300 meters high. There is no indication of flow features located in the materials found at the base of the scarp; however, the area covered by the image mosaic is so small (15 x 15 km) that fluid emplacement of this material cannot be ruled out. Westward of the major scarp are a series of craters (somewhat parallel in trend to the large scarp) which may be secondaries of a large crater out of view or may be aligned depressions related to the formation of scarps in the area. Mass wasting has been seen in the other high resolution images and may be the major process responsible for forming the surface seen at the base of the scarps within the Valhalla ring structure.

The final observation was of a crater chain. This chain is not radial to any known impact structure on

the surface of Callisto. Therefore, it is considered to have been formed by the impact of a split body analogous to the impact of the Shoemaker/Levy-9 split comet impact into Jupiter's atmosphere in July 1995. These images also contain the smooth, low crater frequency surface seen in the other high resolution images. The crater rims all appear to be about the same state of degradation, but contacts are covered by the smooth material, making analysis difficult. The smooth material is equally prevalent both inside the craters of the chain and on the surrounding terrain. The crater density both inside and outside the crater chain, except at the smallest sizes, appears to be lower than that in other measured Valhalla images [9], indicating that this region is either relatively younger or that the crater chain impacts obliterated not only craters within the large chain craters, but also some craters adjacent to it (for example by ejecta emplacement). The slope of the crater size-frequency distribution is, as expected, steeper within the chain craters than immediately outside. Context frames at 400 m/pixel will be acquired on the ninth Galileo orbit (C9) that will aid in understanding both the structural features and the surface texture seen in the high resolution Valhalla images.

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